

Design Steps Towards A High Brightness Electron Impact Ion Source

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The capabilities of focused ion beam (FIB) applications are strongly dependent on the ion source performance. High brightness beams are mandatory in ion-milling to create small features with good erosion rates, as well as in ion-imaging for high lateral resolution with sufficiently high recording signals. In addition the ion species are of importance for many applications, e.g. reactive ions are needed for high secondary ion yields in Secondary Ion Mass Spectrometry (SIMS).

As the ion source we are targeting should be flexible with respect to the choice of ion species, electron impact is the most suitable ionisation technique as it allows to create various ion species by only changing the gas feed to the ion source. In addition to high brightness, a low energy spread of the extracted ion beam is of importance.

Charged particle optics simulation studies have been realised in order to get an estimation of the achievable ion source performance. In a first design concept, a small electron column with thermionic emission from a hairpin filament has been investigated. The electron beam is focused into the ionisation region of the ion source, which consists of two parallel electrodes spaced by 1 mm. The combination of a cylindrical ionisation volume with dimensions in the submillimeter range and an electrode potential difference of only 10 V creates a small potential drop across the ionisation volume and generates a low energy spread ion beam. By setting the ionisation region to a pressure of 0.1 mbar and injecting an electron beam at 1 keV and 50 μ A, a 30 nA Ar^+ ion beam of a 5-25 μ m source size can be extracted through an aperture of 100 μ m. With a half opening beam angle between 5-20 mrad at 6 keV of ion beam energy the reduced brightness B_r is determined to be around 50-55 $\text{A m}^{-2} \text{sr}^{-1} \text{V}^{-1}$. The mentioned range for source size and beam angle is due to a variation of potentials within the ion extraction column. A decrease in source size is accompanied by an increase in beam angle which explains the range of B_r values corresponding to different potential settings. The energy spread of the ion beam defined as full width half maximum value is about 1 eV, which is favourable to limit the influence of chromatic aberrations on the achievable spot size in FIB applications.

Switching to a LaB_6 electron emitter would reduce the ionisation volume by a factor of 10 while keeping a comparable electron current. The benefit for B_r is about a factor of 3 leading to 150 $\text{A m}^{-2} \text{sr}^{-1} \text{V}^{-1}$. However, the required operating pressure is below 10^{-7} mbar which is a hundred times lower than that of the hairpin filament. Gas conductance calculations and measurements have been performed in order to determine how the required vacuum level could be reached in the electron column part of the design.

Comparing the results stated above to conventional electron impact ion sources for which B_r is about 1 $\text{A m}^{-2} \text{sr}^{-1} \text{V}^{-1}$, the here presented design study represents a clear improvement of performance. Current design modifications are expected to lead to further increase the extracted ion current while keeping the same result in terms of ion beam source size and half opening beam angle, resulting in a further enhancement of the brightness of the source.